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MAKING PRODUCT CUSTOMIZATION PROFITABLE

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The main result presented in this paper is the Framework for Product Family Master Plan. This framework supports the identification of a product architecture for companies that customize products and services. The framework has five coherent aspects, the market, product assortment, supply-production, organization and work processes. One of the unique results is that these aspects are linked, which make it possible to make explicit recommendations for an architecture (the way a product family should be structured with clear interfaces), architecture elements and consequences. By means of a case study it is shown that the potential EBIT (Earning Before Interests and Taxes) improvement of the case company is 10%.

Significance: Many companies make customization, but have severe difficulties becoming profitable. This paper suggests a framework for identifying an architecture that can provide a basis for increasing profitability.

Keyword: Product Family Design, Architecture, platform, product development.

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1. INTRODUCTION

For many companies that deliver customized products and solutions it is often very difficult to make satisfactory EBIT (Earning Before Interests and Taxes). Below is an example from a company making customization of building equipment. The Gross Margin (GM) distribution across projects has a variation as shown in figure 1.

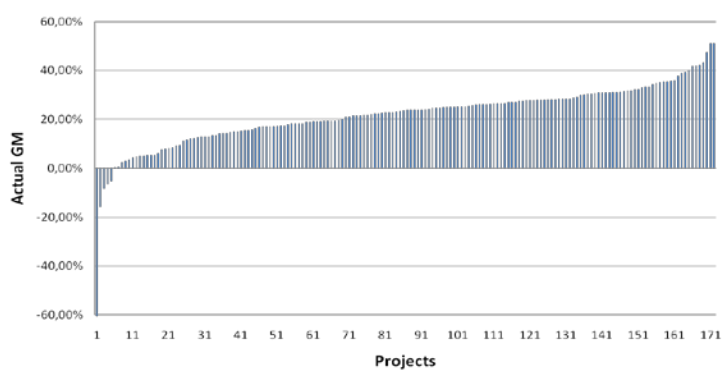

Figure 1: Gross margin for projects

The x-axis shows individual projects in the company and the y axis shows the actual gross margin in each individual project. In the company above all quotations are calculated based on a gross margin of 20%. As the diagram shows, quite a significant amount of projects have a margin far below 20%. What can also be seen is that some projects have a higher margin than 20%. It is clear that there is significant margin deviation in the majority of projects. As a result this, the company has an overall EBIT of a few percent some years and a negative EBIT in other years.

The above situation is no single incident but is more or less the general picture for the 40 companies that we have been working with over the last years, Hvam, Mortensen & Riis (2007). There are exceptions but the majority of the companies making complex engineering customized products have severe problems making a satisfactory EBIT. In periods where it is relatively easy to get new projects these companies could make more money if they were more professional in selecting the profitable customers and projects. The situation today with financial crisis many companies try to shoot at everything, leading to a situation where many projects become even less profitable.

There are certainly many reasons for the lack of ability to make a satisfactory EBIT. This paper is based on the assumption that EBIT can be improved significantly if a more clear architecture for the product assortment is designed and implemented. A clear architecture means that the building blocks in the product assortment and related interfaces are clearly defined. This further means that the organization, processes and systems are designed to handle this architecture. In other words the architecture describes where the company can make profitable projects. A further implication is that a company will then be able to recognize a profitable customer or project upfront. The reason is that a relative stable architecture means that robust and optimized processes can be developed. If the architecture, including core interfaces is changed in each project, it is nearly impossible to develop robust processes across the whole company.

This paper will propose an operational framework, Framework for Product Family Master Plan, which can serve as a basis for identification an explicit architecture. The research is based on PhD, Master and consultancy projects in more than 40 companies mainly within Scandinavia. Before going into the framework, we will first examine some of the barriers for implementing architectures. Then the framework is presented and is then related to other research work and finally experience from application of the framework in an industrial company is presented.

2. BARRIERS FOR MAKING A CLEAR ARCHITECTURE

Most Board of Management teams recognize the need for having a more clear architecture. The phenomena have many different phrasings such as standardization, preferred solutions, platforms, fast track, mass customization, lean processes etc. They all somehow express the intention that there should be two execution processes, a fast track and a standard track. This is shown in the figure below.

Figure 2: Clear distinction between fast track and standard track. Projects within the architecture shall be executed as fast track and projects outside the architecture shall be executed as standard track or simply rejected.

The standard track is based on the architecture and the standard track is covering the remaining projects. Often there is no clear separation between the two tracks leading to a lot of complexity and inefficiency in project execution.

Despite that the vision for many companies is expressed more or less explicit, very few companies seem to be able to implement it. This section will summarize the most common barriers that companies have expressed during architecture projects.

"We deliver value to our customers by delivering exactly what is requested" This will sometimes be true but in many cases not. There are many examples of variety in a product assortment that does not provide value to customers but only add complexity cost in companies. A few examples of this phenomenon are. One company is delivering products with actuators that are bolted, welded and glued. This means that three types of production processes have to mastered, leading to increased cost. Seen from a customer point of view this variety does not add value. Another company is having pressure tanks certified for 4,1 bar, 4,4 bar and 5 bar. In this case certificates and approvals have to developed and maintained without any extra value to the customers.

"We will loose our customers" This might be true, but there is a clear tendency that the companies trying to shoot at everything make significant less money than the one with a clear and focused market strategy. Without an architecture it is difficult to recognize a profitable customer. An architecture makes it more clear where a company can develop and deliver customized products with satisfactory EBIT. Thereby a significant better decision basis is available for accepting or rejecting a project or a customer. Some of the companies that we have studied have reduced turnover due to fewer customers, but the customers they have contribute to an increased margin.

"Product assortment ownership is unclear" Companies develop products within projects with a clear responsibility as long as it is a project. But after the project and on portfolio level the responsibility is often unclear. There are procedures for how to introduce new products and components, but often there are no procedures for removing them. The criteria for accepting or rejecting a project are often very fuzzy.

"We do not know where to start" In many companies the product assortment is so complex that it is difficult to get an overview. Over the years product programs often become extremely complex, due to customization, acquisition of new companies and reinventing the wheel in projects.

"Architectures is a looser project – do not touch it" To succeed with an architecture project commitment from sales, engineering and production is necessary. In sales a company might have so say no to customers, in engineering a more clear focus on sharing and reuse is needed and in production capabilities have to be adjusted according to the architecture and vice versa. Who is responsible for the link between sales, engineering and production? Ultimately it is the CEO. Often we see architecture initiatives isolated in the sales, engineering and production but they are not coordinated and do therefore not create significant benefits.

"Benefits are difficult to quantify" It is difficult to prove that companies with a more clear architecture make more money than companies without, but among the companies that we have studied there is a clear tendency. Among the most important reasons why benefits are difficult to quantify is that savings often are related to decreased overhead costs. The increased ability to develop new products, shorter lead time is not easy to quantify. Many sophisticated techniques are available in literature, such as activity based costing and total cost management. In the companies we work with more simple techniques have been utilized. The main technique has just been to evaluate what task are added or removed in each functional area in a company.

There is no simple answer to address the above barriers, but one aspect that can support decision making is a systematic approach to identify what could be concrete architectures, architecture elements and benefits. One such approach is the Product Family Master Plan Framework.

3. FRAMEWORK FOR PRODUCT FAMILY MASTER PLAN

This section will briefly describe the framework that has been utilized for analyzing a company and the product assortment with the purpose of identifying an architecture. The intention has been to describe a framework which can support answering the following questions:

1) What are the existing variety of the product assortment, seen from customer, functionality and part point of view?
2) Is the variety creating value for the customers?
3) What sort of complexity is created in production, due to product variety
4) What are existing variety in production and production processes?

5) Which production processes are creating value?
6) What variety exists in the work processes when customer specific solutions are designed?
7) What are the dispositional relation between the product assortment variety and the order and development process?

The product modeling basis in the Product Family Master Plan Framework is the Theory of Technical Systems (TTS), Hubka (1988) and Theory of Domains (ToD), Andreasen (1980). According to TTS and ToD a product can be modeled from four points of views: process, function organ and part. A process describes the transformation that a product is able to do. A coffee machine is able to carry out a process where water and coffee beans are united in to coffee. The functions are defined as the purposeful effects necessary to carry out the process mentioned above. In the coffee machine example the effects necessary are creation of heat, filter the coffee beans and the water. The organs are the elements which are able to realize the functions. Examples of organs in a coffee machine are the heating element, the filter, the can and the chassis. The parts are the physical elements which in an interplay is able to realize the organs. Example of parts in e.g. the heating element might be the wires, the screws, and plates. In the framework processes and function view are combined in to what is called a customer view. The customer view is then the subset of the processes and functions that are relevant seen from a customer point of view.

Object oriented models consist of objects and relations. An object is characterized by its identity, structure and behavior. According to Coad & Yourdon (1991), relations can be whole-part, generalization - specialization, message connection and instance connections. Whole-part (part of) is relations between entirety and elements. Generalization - specialization (kind of) are relations between super and sub classes. Message connections are data flow between objects, e.g. that calculation in one object requires data from another object. Instance connections are relations between classes and instances. TTS and ToD is describing single products whereas object oriented modeling adds variety in such a way that product families can be modeled.

The Product Family Master Plan (PFMP) is originally proposed by Harlou (2006) and is based on TTS, ToD and Object oriented modeling. In this paper the PFMP is expanded by means of a market, supply, organization and work process dimension. The totality is named Framework for Product Family Master Plan, se figure 3 below.

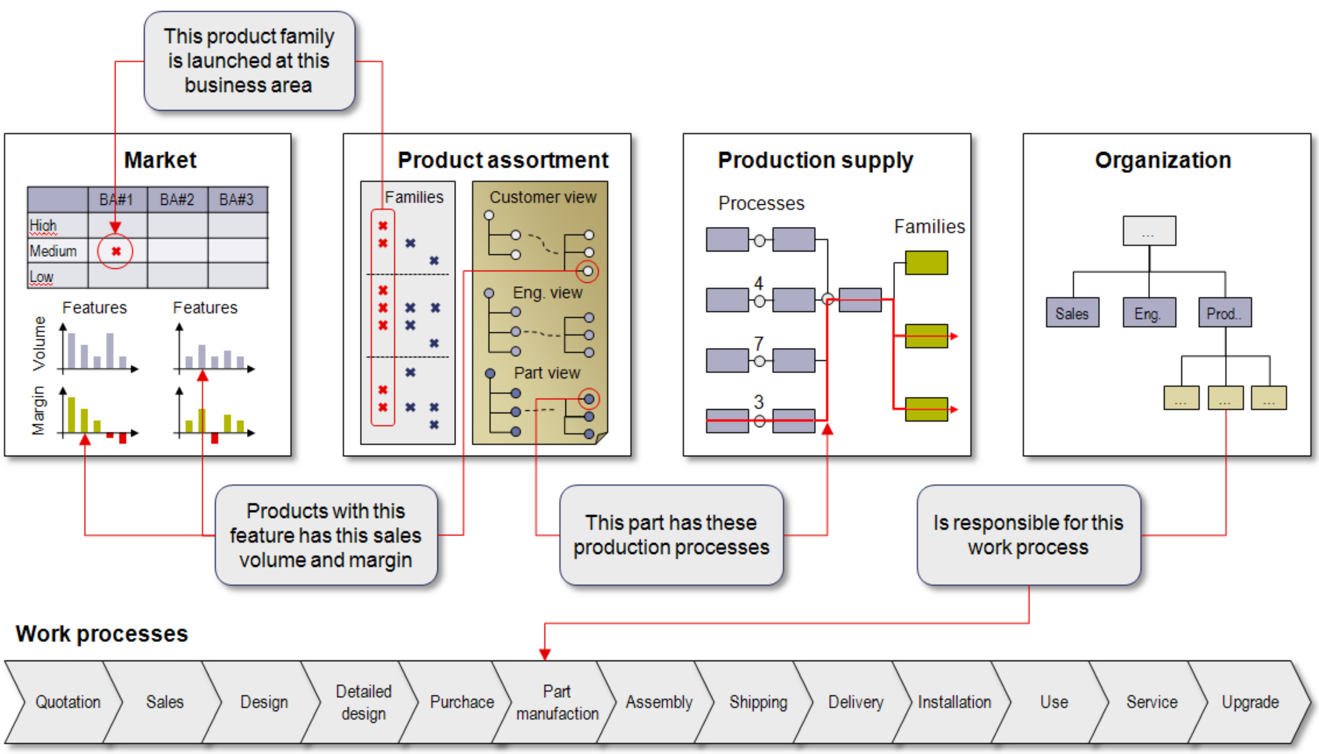

Figure 3: Framework for Product Family Master Plan

The Product Family Master Plan (PFMP) Framework consists of five aspects. The market, product assortment, production supply, organization and work process aspect. In this section the framework and the contents is explained further.

Product Assortment aspect
Starting with the Product aspect, it consists of a customer view, engineering view and part view. Each view consist of two sub structures a part_of structure and a kind_of structure. In the customer view all features that are of importance to the customers are described. The engineering view contains the functional units (organs in the TTS) and variants within the product assortment. The part view describes the physical elements and variants of the products.

What is of special importance is the links between the views. Each of the views is causally linked meaning that certain types of traceability can be described. The relation between customer view and engineering view describes how certain customer features are realized by means of certain functional units. The relation between engineering view and part view explains how functionality is realized by means of physical parts and sub-assemblies. Reading the from the part view to the engineering view explains how a certain part contributes to delivering functionality of the products. From the engineering view to customer view the relation describes how functional units deliver customer features and, hopefully, value to the customer.

From these relations a number of important conclusions can be derived. Some examples are:

- The more relations that exist from a certain feature in the customer view to functional units in the engineering view, the more complexity are the product assortment inherent. This means that if a feature in the customer view is changed; all the related functional units and subsequent parts have to be changed or updated.

- The relations between the engineering view and the customer view often reveal that certain functional units in the engineering view have no explicit relations to the customer view, meaning that a none-value adding variety has been added to the product assortment.

Further more the commercial variants of the product assortment are mapped. This means that it can be clearly seen what in terms of customer features, functional units (organs) and parts that are shared across the Product Family of the products. In figure 3 three product families, A, B and C are described.

Market aspect
In this area two sub aspects are described. The Power Tower matrix (shown in the upper part of the market aspect in figure 3), Meyer & Lehnerd (1997) sales volume and turnover for each customer feature is mapped. The Power Tower has two dimensions. The first one is business areas (BA in figure 3) and the second one is the high, medium and low end products. The power tower provides a good overview on how the product families are covering the whole market. When deciding on an architecture, it is of high importance to determine which areas in the Power Tower matrix it shall cover. Mapping the customer features in terms of sales volume and contribution margin provides a good overview on the consequences of adding or removing a feature to the product assortment.

Production – supply aspect
This is in principle the same as the product assortment aspect – just that the production processes are the modeling object. The principle here is a generic process diagram, meaning that all process is mapped on a generic level. The production flow of each family is then mapped in the process diagram. For each process, the numbers of part or assembly variants are described (described in the circle after each process). A shadow behind the boxes indicates that variants of the process exist, e.g. two different welding processes are carried out. The production flow for each family is described in the production – supply aspect (this is shown by means of the lines connecting the boxes and end up in individual families, A, B, and C). Mapping the production flow of individual families, gives an overview of how much of the production processes and equipment that are shared across the product families.

Organization aspect
In this aspect the persons and departments being active in the sales, delivery and production of a product variants is mapped. The purpose is to see how many times change of ownership is carried out in the chain of work processes. Mapping the different IT systems utilized also provides valuable information for determining the complexity that have to be handled.

Work processes
In this aspect the generic work process in the company is mapped, i.e. quotation, sales, design, purchase, quality etc. When deciding on an architecture it is easy to optimize against a few work processes, but it has to be optimized with respect to whole work process chain in order to provide significant benefits, e.g. lead time reduction. The next section will briefly

explain the relations between the different aspects. It is due to the explicit relations that the most important conclusions can be derived.

Product assortment – Market aspects: There are two different relations shown in figure 3. The first one is relating product families and the power tower. This relation shows in which business areas the product families are marketed. The second relation shows how classes of features relates to product sales and volumes.

Product assortment – Production supply aspects: This relation shows how individual parts are manufactured in a sequence of production processes. By means of this relation commonality between parts and production processes can be visualized.

Organization – work process aspects: The relation shows which part of the organization that is responsible for the individual work processes.

In section 5 the case study will explain how the above framework has been utilized as basis for making decisions on a product family architecture.

4. EXISTING APPROACHES IN LITERATURE

The following review is based on the results from the phd dissertation of Morten Kvist, Kvist (2009).

Modular Function Deployment: The modular function deployment (MFD), Ericsson & Erixon, (1999) builds largely on the methodology of the QFD and on the formulation of eight so-called module drivers. The purpose of MFD is to enable cross functional teams (including mainly marketing, development and production personnel) to create a mapping from the physical structure of the products within a family to the functional structure of those products and to ensure that the functional structure corresponds to the demands of the customers. Modular Function Deployment method consists of five consecutive steps. Customer requirements are mapped to functional criteria and subsystem design characteristics and subsequently forming a physical design in which a modular architecture supports a carefully selected set of modularisation incentives called module drivers.

Design Structure Matrix: This approach takes a starting point in the decomposition of a product into components/systems and an identification of interfaces/relations among these, Pimmler & Eppinger, (1994), Höltta-Otto & De Weck, (2007). By the use of algorithms, it is possible to encapsulate components into modules or chunks that are closely related to each other from an interaction point of view [Steward, 1981]. This process is referred to as clustering. The outcome of a DSM is a proposal for a future modular product architecture.

Generic Bill of Materials: The generic BOM originate from the assemble-to-order environment, van Veen & Wortmann, (1987) The end-products typically have a number of features for which a number of options are available to choose from. Not many options are required in order to make the number of combinations (i.e. end-products) enormous. The number of end-products can easily become too large to able to define specific BOM's for every single combination. Furthermore, forecasting, BOM-storage and maintenance become unmanageable. The generic BOM is a concept that is introduced to enable creation of a specific manufacturing BOM when the customer places an order, by replacing. The generic BOM is used to describe related products in one all-embracing model by using generic and specific items.

Decision tree: The decision tree, Rea, (1965)is used by Tiihonen & Soininen (1997)as a product configuration model, which basically represents all the valid combinations of the components that can be used to obtain the desired functions for the customer. The product configuration model, Mesihovic & Malmqvist (2004). The decision tree presents the multitude of component variety within a product family and by the use of positive combinatory relationships (e.g. if "engine size"=D13 then "engine power" must be 360 or 420 hp) and/or incompatibility relations (e.g. if "engine size"=D13 then "engine power" cannot be 220 or 700 hp) it defines the possible product configurations.

Value analysis: Value Analysis is a discipline founded at General Electric in the late 1940's , Fowler (1990). In short, value analysis is a methodology that has as its purpose to relate cost with functions in a product. It is a stepwise methodology in which a product is partitioned into smaller constituents for further analysis – that may be analysis of cost or value. Value is not the same as the Japanese idea of customer value we may see within the lean paradigm. Value is specifically defined as the "worth" relative to cost, i.e. value = worth/cost. Worth in this sense actually resembles the idea of customer value in lean very well. It is a denominator of those aspects, functions and features a customer wants to pay extra for. The customer is regarded as the downstream stakeholders in the supply chain. Worth is – in other words – a function of the totality of needs and demands of the customers, the customers' customers, the distribution channel etc. Some practitioners try to quantify worth and relate it directly to cost. Obviously cost is rather quantitative and measurable in hard currency, while "worth" is a more soft and qualitative size. Whether qualitative or quantitative, value has a focus on identifying value elements from a customer perspective and relate it directly to the functions of the product and thereby indirectly to the way the products are built.

Function structures: The function-based design methods are characterized by the establishing either a function model Pahl & Beitz, (1996), Otto & Wood (2001) or the schematics of the product Ulrich & Eppinger (2000). The function structure describes the flow of material, data, and energy through sub-functions of the product using a set of rules (e.g. the rules that are referred to as the functional basis which basically is a common language to describe functional elements. The schematic of the product is somewhat similar to the function model. But where the function model describes the product using functional elements the schematics on the other hand can describe both functional and physical elements, whichever being the most meaningful. Having established an understanding of the functional structure of the product some methods base identification of modules on experience and some simple guidelines, i.e. a rather qualitative approach Pahl & Beitz (1996), Otto & Wood (2001), Ulrich & Eppinger (2000), [Pimmler & Eppinger, 1994]. Basically, these methods identify potential modules in a way similar to the way the MFD method makes use of the so-called module drivers.

Multi criteria assessment: Otto & Hölttä-Otto (2007) presents a technique based on multi-criteria assessment where platform concepts are given a score based on a set of different weighted criteria. Although, the method is designed to be used for screening of preliminary platform concepts, and not - as it is the focus of this research - analysis and re-design of product families, the method include analysis aspects that should be considered. The method is based on relatively quantitative metric adapted from the field of modularity, platform design, and product development in general (e.g. functional structure, DSM, commonality indices, etc.).

Value stream mapping: Most value stream mapping tools has a focus on information and physical goods passing through the supply chain. The value stream is consequently often perceived as the flow of materials through the value adding processes. There are several value stream mapping tools Womack & Jones (2003), Rother & Shook (1998). This section describes the "traditional" value stream mapping tool. Other tools or methods re describe in the subsequent sections. A less graphical depiction of the value stream is a process activity map. It is a schematic representation of the critical path of a production. It is basically a matrix containing a mapping between process steps and machines, time consumption and distance along with other factors of choice. This tool may be used in conjunction with the traditional value stream map or as a preparation of that.

Conclusion: It is clear that all the above approach can play a role in identifying an architecture for a product family or product assortment. The contribution of the Framework for Product Family Master Plan is mainly the relations between the different aspects. Most properties of a company and product assortment are so-called relational properties, Andreasen (1994). This means that e.g. production cost is the result of a meeting or relation between a product and a production system. The existing approaches main focuses on single aspects and not the interplay. Value stream mapping is widely used in lean projects. Often the product dimension is not taken into consideration. This is particularly relevant for companies manufacturing customized products and solutions. It is difficult to achieve a lean process on a complex product assortment with high number of part variants and unclear interfaces. Most of the data necessary for filling out the framework is often available in companies but is distributed across IT system, departments and persons. Making the relations visual is often very beneficial and makes it possible to make conclusions that are otherwise not possible.

5. INDUSTRIAL EXAMPLE: COOLING SYSTEMS

The case company is selling, designing, manufacturing and delivering customer specific cooling solutions for large OEM (Original Equipment Manufacturing) customers. The company has been grooving significantly over the last 10 years. One of the reasons is that their customers have grown significantly. While the customers have had a profitable growth, then the case company has experienced a declining EBIT over the last years.

The business situation for the case company can be characterized as follows:

- Increased pressure on prices –because customers becomes bigger and is thereby obtaining higher barging power

- Customers becomes global and is therefore expecting global delivery to an increased number of design and manufacturing sites
- The expectations on shorter lead time for quotations is expressed clearly by the customers
- Competition from EU and China is expected to be further intensified
- Shorter time to market for new products is necessary to maintain the current market share.

To address the above challenges many initiatives have been started – one of them is investigation of the potential benefits of a having a more clear architecture for the products and solutions.

Over a couple of month's data for were collected and structured as described in the Framework for Product Family Master Plan. Due to confidentiality and practicality (10 A0 posters for describing the contents of the whole framework) the actual posters and contents are not shown in this paper. Among the important conclusions from utilizing the framework were:

- The dimensioning tool utilized in the sales phase is utilized to calculate the critical parts in the solutions. The consequence is that each solution will be unique. This will again lead to variety that is not value creating to the customers.

- Many classes of parts exist, e.g. tubing equipment for 4,1, 4,2 and 4,3 bars – this is also an example of non value creating variety.

- The product structure shows a complex mapping between the customer, engineering and part view. This means that each time a customer feature shall be different from the previous; it is a complex engineering task. In production it will lead to a new variant that have to be managed.

- A visit to a key customer revealed that a lot of the variety in terms of connections, fasteners, approvals etc was not very critical to the design of OEM equipment.

- There was significant variety in the manufacturing processes which is mainly adding complexity and will increase lead time.

- In many of the cooling systems the customer order decoupling point is placed very early in the production process chain which again will lead to long lead time and production complexity in general.

- There were in period's significant quality problems and related costs. One of the reasoning for this is that the amount of manufacturing processes made it difficult really to master them on world class level.

- Some of the projects is characterized by reinventing the wheel, meaning that the solutions already exists, but was designed again due to lack of overview concerning existing solutions.

The systematic mapping according to the framework was considered as being very beneficial both to the management team and senior personnel in sales, engineering and manufacturing.

The next step was to propose an architecture for the product assortment. The result of this design work is shown below, in figure 4. By critically looking at the framework for product family master plan an architecture with standardized interfaces were proposed at shown below.

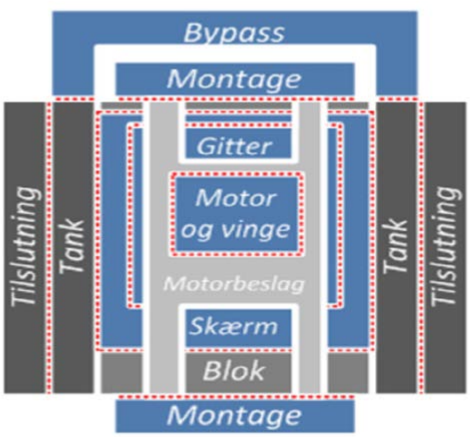

Figure 4: Proposed architecture for cooling solutions, in Danish

Among the main benefits estimated was:

- Reduction of number of parts from 600 to approximately 100
- Reduction of direct cost with 10%
- Reduction of complexity cost in the whole organization by 10%
- Significant reduction of lead time for new prototypes
- Significant reduction of lead time for new products

It was estimated that the new architecture will be able to cover 65% of the total sales, which means that that EBIT will be increased by 10% over a period of two years. At the moment a detailed design of critical components is carried out in order to verify the above benefits.

6. CONCLUSIONS

The main result from this work is the Framework for Product Family Master Plan. This framework can be utilized as a basis for systematic analysis of companies making customer or market variants of products. The framework enables a company to point out which of the activities and product elements that provide value to the customers. This serves as a valuable basis for identifying an architecture of a product assortment or product family. A good architecture enables a company to recognize profitable customers and projects. The case study indicates that a significant improvement of EBIT is possible with a fully implemented architecture. As the case study shows development of an architecture is not necessary a complex development project, but in many cases more a question of making decisions on preferred sub solutions.

A real implementation of the architecture is a very challenging task, because it has to work across sales, engineering and production. Many preconditions for a successful implementation exist, e.g. a focused market strategy, a modern IT infrastructure and a proper working product management. Due to the highly cross functional nature and market strategic impact the responsibility ultimately have to be anchored by the CEO and board of management.

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